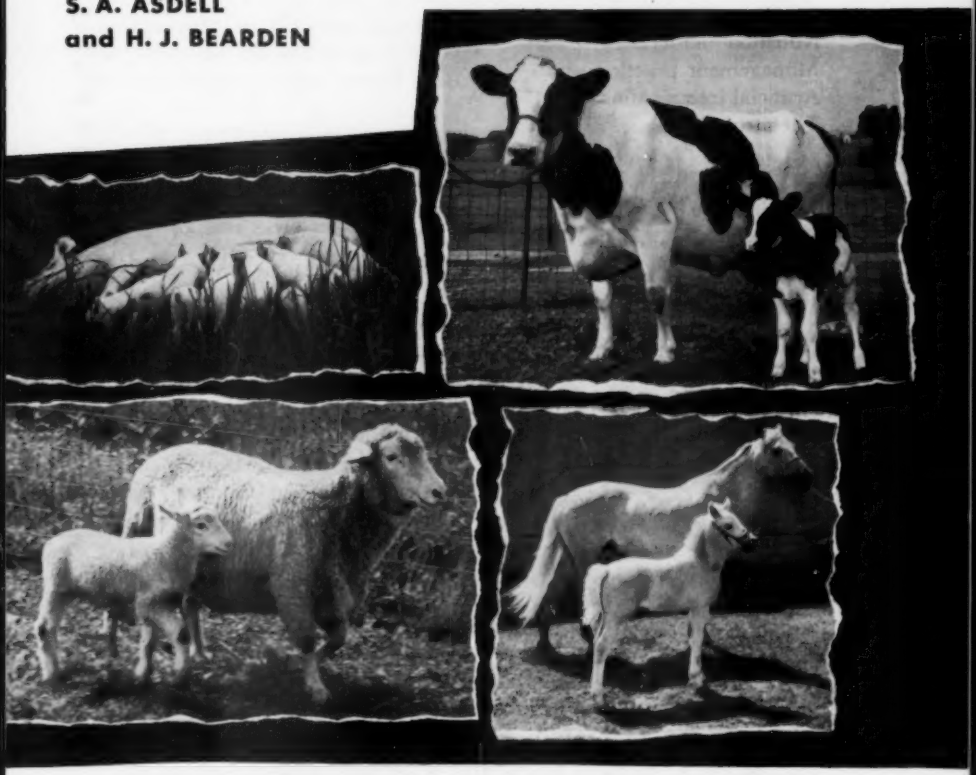
REPRODUCTION OF FARM ANIMALS

S. A. ASDELL
and H. J. BEARDEN



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Reproduction of Farm Animals

S. A. Asdell and H. J. Bearden

This bulletin explains in as non-technical language as possible the process of reproduction of farm animals. First the reproductive organs are described and their functions explained. Then the classes of livestock, except poultry, are discussed and conditions peculiar to each are given in some detail. An attempt is made throughout to relate scientific knowledge with the best practices in animal husbandry.

The Male Reproductive System

In domestic animals, except birds, the two testes are enclosed in separate compartments in a sac, or scrotum, suspended to the rear of the animals. They are suspended in this manner because the testes require a temperature somewhat below that of the body for the production of fertile spermatozoa. The scrotum acts as a radiator to dissipate heat. When the testes are retained in the body, as in the ridgeling or cryptorchid, spermatozoa are not formed and the animal is therefore sterile. If one testis is in the scrotum the male is usually fertile because that one testis is able to produce spermatozoa. Such a male should not be used for breeding because the condition tends to be inherited and may be passed on to male offspring through several generations. The testes perform two functions: one, the formation of the spermatozoa, or male germ cells, and, two, the production of hormones, or chemical substances, that pass into the blood to cause the formation of all the characterstics that are known as maleness. Figure 1 shows a diagram of a bull's reproductive organs.

Each testis is connected with the body by a cord containing a canal that carries the spermatozoa to the penis. The cord also contains muscles, nerves, and blood vessels that maintain the testes. If the cord is crushed and the blood supply to the testes is cut off, these organs will degenerate.

The penis is the common outlet for urine and spermatozoa. During sexual excitement spaces within the penis fill with blood and it becomes enlarged. With the aid of muscles, it is extruded so that it may enter the female vagina and deposit the semen.

The spermatozoa are extremely minute free-swimming organisms with two parts, a head and a long tail. The head is the essential portion because

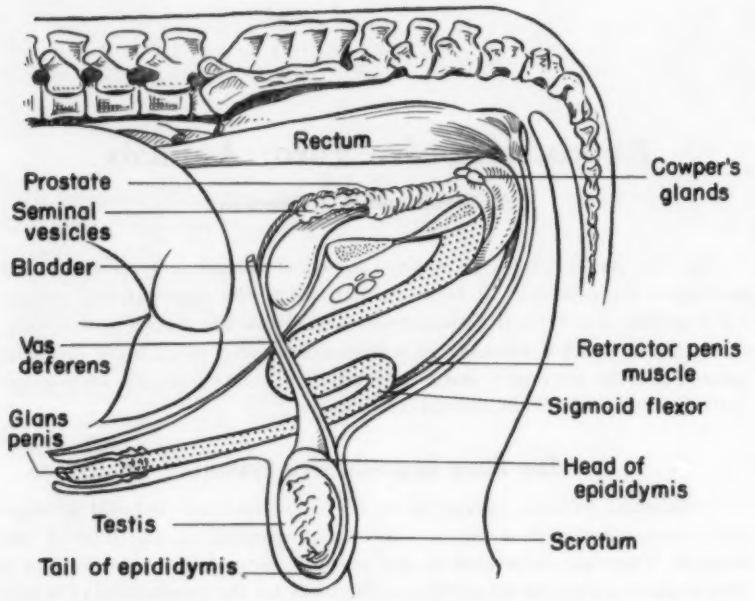

Figure 1. Diagram of the reproductive organs of the bull and their location in the body.

Figure 2. Spermatozoa of a bull.

it carries the material needed to fertilize the egg. The tail, many times longer than the head, propels the spermatozoa in its search for the eggs. Figure 2 shows a group of bull sperm enlarged many times.

Within the testis the spermatozoa are motionless, but as they reach the penis they are mixed with fluids from various glands which help stimulate them to activity. This activity also results in part from a reduction in the amount of carbon dioxide in the fluid surrounding the sperm. The principal accessory glands supplying this

fluid portion are the prostate, at the base of the urinary bladder, and the seminal vesicles, a pair of which are close to the prostate. The mixed spermatozoa and fluids are called semen, and it is this mixture that enters the female tract. Urine is prevented from contaminating the semen at the time of service by the temporary closure of the canal of the penis between the bladder and the point of entrance of the spermatozoa.

The Female Reproductive System

The principal female organs are the ovaries. These, unlike the testes of the male, are found in the body cavity. They are connected with the inner body wall by attachments that carry blood vessels. Each ovary contains large numbers of eggs. Each egg is about 1/130 of an inch in diameter, and is enclosed in a small sac called a *follicle* or ovisac. As the female comes in heat, one or more of these follicles enlarge until the follicle wall reaches the surface of the ovary. Much of this enlargement is caused by a secretion of fluid within the follicles. Eventually, during or just after the heat period, the follicle bursts and the egg, together with the fluid, is liberated.

The ovaries are partially surrounded by membranous funnels that catch the eggs as they are shed and guide them in to the oviducts. The latter are tubular structures that transport the eggs to the womb, or uterus. During their passage down these narrow tubes, the eggs are usually fertilized by the spermatozoa which have been carried up to meet them. A sketch of the sow's reproductive organs is shown in figure 3.

The oviducts enter the horns of the uterus. This organ is a muscular structure with two horns that unite into a single body lying in the midline of the animal. The body of the uterus narrows down to a mouth, or cervix that opens into the vagina or female passage. During pregnancy the cervix is closed by a plug of thick mucus. At the heat period the cervix dilates to afford ready passage for the spermatozoa. The inner lining of the uterus is a spongy tissue richly supplied with blood vessels. The fertilized eggs develop within the uterine cavity and they send out membranes that become connected with the spongy bed; through these membranes nourishment is drawn from the maternal tissues to supply the needs of the developing eggs or fetuses. In the ruminants (cow, sheep and goat) the interior of the uterus is provided with a num-

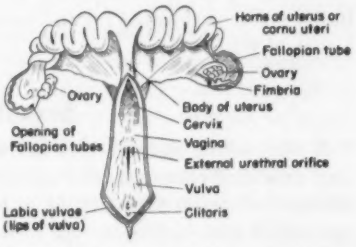

Figure 3. Diagram of the reproductive organs of a sow.

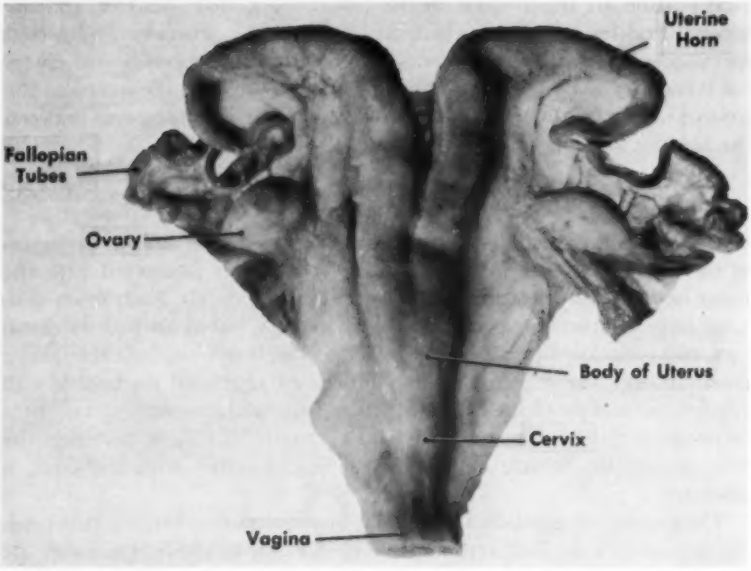

Figure 4. Reproductive organs of a ewe. The vagina and vulva are not shown.

ber of caruncles or button-like elevations. Similar processes on the developing egg membranes become fastened to these caruncles. Nutrients from the mother's blood cross these points of attachment and are absorbed into the fetal blood. Figure 4 shows the reproductive organs of the ewe.

The vagina is a wide tube whose walls are normally pressed together. The urethra, a tube that carries urine from the bladder, opens into the posterior end of the vagina. The vulva, the exterior part of the reproductive organs, connects with the vagina. A small rod-like structure, the clitoris, projects into the vulva. This is the female equivalent to the penis but it is not perforated for the passage of urine. The vulva is enclosed by a pair of lips, or labia.

Sexual Maturity

A very young animal does not come in heat or produce spermatozoa, and its sexual characteristics are not apparent. Gradually, the characteristic signs of sexual maturity, or *puberty* appear. These signs are the development of male or female type of body conformation, voice, and attraction towards the opposite sex. They come at a time when the infantile testes and ovaries begin to develop and become functional.

The gradual onset of puberty is brought about by the secretion of gonadotrophic hormones by the pituitary gland, located at the base of the brain. These hormones travel in the blood to the ovaries or testes where they cause these organs to begin to function. After this has happened the female hormones, estrogen and progesterone, produced by the ovaries, and the male hormone, testosterone, produced by the testes, are responsible for development and maintenance of the female and male characteristics described above. The onset of puberty varies with different breeds and kinds of animals. The level of nutrition may markedly affect the time of its onset. In dairy cattle, puberty is brought on earlier by better feeding and its appearance is more closely related to size of the animal than to age. However, in gilts, self-feeding may delay puberty when the results are compared with the effects of feeding at two-thirds the self-fed rate.

At the point of development when the gonadotrophic hormones are produced, the production of growth hormone, the substance that causes animals to grow, begins to diminish. The growth rate also diminishes but does not stop. In dairy cattle growth will continue through the second lactation if sufficient feed is supplied.

It is possible to induce a premature sexual maturity in very young animals, particularly in females, by injecting extracts of pituitary glands, thereby reinforcing the supply of secretion provided by the animal's own gland. This has been done experimentally, but has no place in animal husbandry because the general body development in these artificially precocious animals is not sufficient for them to supply the nutritive needs of functioning sexual organs.

First breeding should not be too early (see recommendations for each class of livestock in this bulletin). Delayed breeding also is to be avoided. Fertility tends to be impaired with long delays in breeding.

The Sexual Cycle

In wild animals the normal female comes into heat for a short time at one or more definite seasons of the year. The breeding season is usually in the spring or fall or both. This tendency is related to the changes in the amount of daylight at these seasons. Spring breeders can be made to reproduce earlier than usual by increasing the amount of light to which they are exposed during the winter months; fall breeders come in heat earlier if they are kept in the dark for part of the day during summer.

The duration of pregnancy is usually related to the time of breeding in order that the young shall be born at the time of year in which most food is available. Foals and lambs are born in the spring when growing grass is soon available to supplement the mother's milk.

Domestication, with the increase in food supply, selection, and better care of the animals, has increased the length of the annual period during which reproduction is possible. The Dorset and Merino sheep have longer breeding seasons than other breeds, but the Mouflon, or semi-wild sheep, has a very restricted season. There are indications that the forerunners of the cow had a much more restricted breeding season than that of cows today.

Female domesticated animals will allow service only at the time of heat, or estrus. At this time one or more follicles in the ovaries become enlarged and ready to burst. The fluid within these follicles contains substances called estrogens. These pass into the blood stream and then to the brain with the result that the females become sexually excited. This occurs as the follicles ripen, so that the desire for service is present when the eggs are about to be shed. This ensures the presence of spermatozoa at the time when they are needed to fertilize the eggs.

When an egg has been shed, the cavity left by the ruptured follicle becomes filled with a yellowish tissue called the *yellow body*, or *corpus luteum*. This body has important functions. It secretes a hormone called progesterone. While this substance is being secreted no more follicles ripen or shed their eggs. Since the corpus luteum persists during pregnancy, new pregnancies cannot be started when young are already in the womb (uterus). The young in the uterus are thus all of one age and are born together in the same state of growth. The corpus luteum also plays an important part in the maintenance of pregnancy. If it is removed, at least in early pregnancy, abortion results. If pregnancy does not occur, the yellow body persists for a short time and then disappears, allowing a new follicle and egg to mature.

The normal sequence of events in the sexual cycle is as follows: In the unmated female there is a period of preparation during which the follicle and its egg are maturing. At the same time the blood supply to the walls of the uterus increases and the spongy layer becomes thicker. The vaginal wall also thickens as a preparation for service. Next the egg becomes ripe and estrogens pass into the blood from the follicle in increasing amounts, causing the desire for service. The vulva enlarges slightly, and the cervix dilates. As the female goes out of heat, or soon after, the egg is shed and the corpus luteum begins to grow. If the egg meets a spermatozoon as it travels down the oviduct, it is fertilized. An egg before fertilization and one after fertilization can be seen in figure 5. The glands in the spongy layer of the uterus enlarge and secrete a milky fluid. For 35 to 40 days in the cow, until the membranes have grown sufficiently to absorb nourishment directly from the walls of the uterus, the fertilized egg is nourished by this fluid.

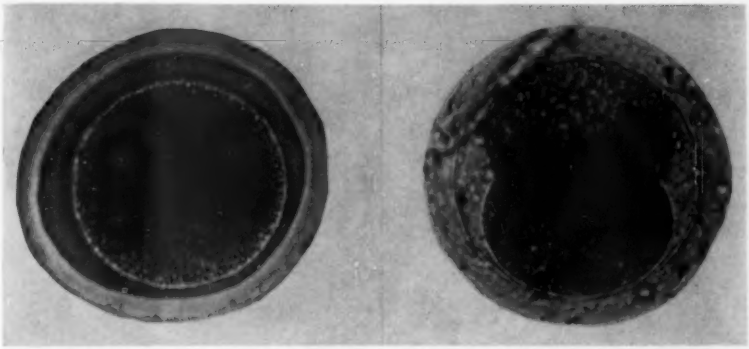

Figure 5. Eggs from cows. *Left,* unfertilized egg. *Right,* egg fertilized by a spermatozoan; the egg has divided into two cells, the first stage in the formation of the calf.

If pregnancy does not occur, the egg degenerates and is absorbed or passes out through the vagina. Under these circumstances, the corpus luteum remains effective for a short time only. The wall of the uterus assumes a state of rest instead of making the growth seen in pregnancy. The uterine glands become smaller and a new cycle of changes begins with the ripening of a new follicle.

Occasionally the follicles fail to rupture and they may enlarge and persist. Such an enlarged follicle is called a cyst. It produces estrogen, the female sex hormone, and the affected animal tends to be in heat continuously or to have prolonged heat periods at short intervals. Cows with cystic ovaries are often called nymphomaniacs or chronic bullers. A cystic ovary is shown in figure 6. Cows with cystic ovaries can be bred but do not conceive because the egg is not shed in the usual way. About 20 percent to 25 percent of cows with cystic ovaries show no symptoms of heat at all. Various methods of treatment are possible. In an experiment conducted by the New York State Veterinary College, 273 cows with cystic ovaries were treated with one of two gonadotrophic hormones. Seventy-three percent of these cows recovered and conceived. Some recovery also may be expected if the cysts are ruptured by applying pressure to them through the rectal wall. The condition of nymphomania is seen more frequently in females in which breeding has been delayed. This is especially true in the mare, the one domestic species in which regular breeding is not always insisted upon.

Another form of sterility is found if the corpus luteum (yellow body) persists. If this happens the regular function of suppressing follicular growth follows, and although she is not pregnant, the female does not come in

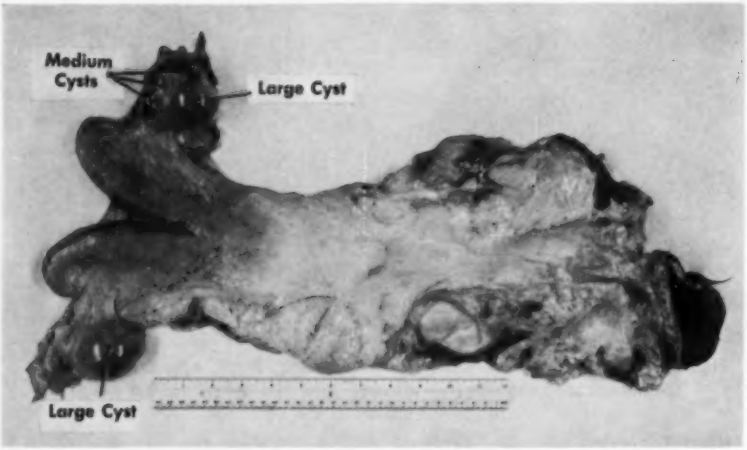

Figure 6. Reproductive organs of a cow with cystic ovaries.

heat. The persisting corpus luteum may be the result of other hormonal imbalances. Accordingly, hormonal treatment is frequently effective. In some cases the veterinarian may cause the cow to come in heat if he removes the persistent corpus luteum but there is some danger of permanent damage resulting from adhesions or hemorrhage. Treatment is not always successful for either this condition or nymphomania because there may be underlying causes that result in a recurrence of the trouble.

Pregnancy and Birth

If the egg has been fertilized and implanted, the developing fetus is nourished through the maternal blood supply. Nutritive fluids pass from the uterus to the placenta across their points of attachments and from the placenta through the umbilical cord to the fetus itself (see figure 8). Waste products pass back by the same route to the maternal blood stream and are eliminated through the mother's lungs and kidneys.

The embryo develops gradually; the head, the nervous system, and the blood vessels are the first permanent structures to appear. Figure 7 shows a 33-day old embryo taken from a cow. The embryo is surrounded by two membranous bags, each filled with fluid, one floating within the other. This fluid protects the developing young from shocks and jars caused by the movements of the mother. At first the embryo lies on its back, but towards the end of pregnancy it turns over so that the head lies between the fore feet and points toward the mouth of the uterus.

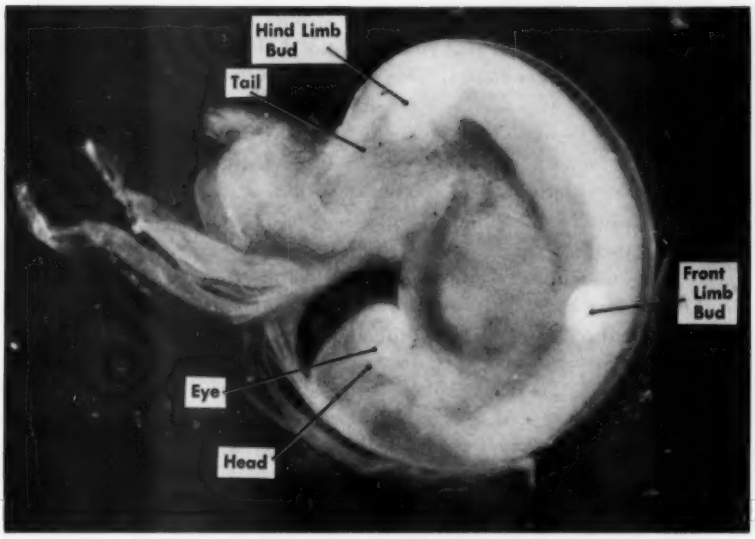

Figure 7. Thirty-three-day-old bovine embryo.

The reason for the variation in the duration of pregnancy in different species is unknown, but with the possible exception of the mare, the time at which birth occurs is connected with the degeneration of the corpus luteum. Following this degeneration the muscles of the uterus, which have been inactive during pregnancy, begin to contract, gradually forcing the fetus into the neck of the uterus. In preparation for the act of birth, the mouth of the uterus and the vagina enlarge considerably, and the framework surrounding the hind quarters of the mother relaxes. In the cow this may be seen externally by the dropping at the tail head, a sign of approaching calving. These preparations afford a larger passage for the young animal. Gradually the force of the uterine contractions increases, and conscious straining of the abdominal muscles assists in the expulsion of the young animal. The first structure to appear at the vulva is the membrane or water bag. Then the animal itself is gradually expelled, but for a time it usually remains attached to the afterbirth by the umbilical cord.

Generally, the smaller the species of animal, the greater the number of young produced at a birth and the shorter the duration of pregnancy. The rat and the mouse produce more young and carry them for a shorter time than do the cat and the dog. The horse and the cow usually produce one at a time; the sheep produces one to three. The pig is an exception to

this rule; the number of young in this species is usually five to twelve. Within species, however, this rule does not hold, for the larger animals usually produce larger litters. This is especially true in the rabbit.

The number of eggs shed is the principal factor in determining the size of the litter. In the cow and the horse, as a rule, one egg is shed at a time, and consequently the number of young born is one. In the sheep one to three eggs are usually shed at each heat period, and the number of young at a birth is increased.

The number of eggs shed, and the number of young, is controlled by the amount of secretion from the pituitary gland. Young sows, for instance, produce smaller litters than mature sows, and it is known that the number of eggs shed at one time by the younger sows is less than it is for the older ones. Possibly the amount of pituitary secretion is influenced by nutrition. Half-starved animals are relatively infertile, but sheep that have been kept under range or semi-range conditions may be induced to ripen more eggs by a period of heavier feeding a week or two before the breeding season. This practice of 'flushing' ewes is used widely in England and Scotland and has been found to yield good results.

In the pig, where the number of eggs shed is large, the number of young developing in the uterus is usually smaller than the number of eggs shed. Some of the eggs are lost and never become implanted; others are implanted, grow for a time, and then die. Up to one-third of the eggs shed are lost in this manner. The dead embryos sometimes can be recognized by the birth of mummified remains with the normal litter. This premature death usually is not the result of faulty nutrition or of overcrowding in the uterus. Disease is not a factor or all of the young would be affected. The number of such deaths varies considerably in different strains.

In all classes of livestock, some early mortality results from inherited factors acting on the mother. The manner in which these factors work is still unknown. Because it may be nature's way of getting rid of "bad eggs" or "bad sperm" there may be some advantage in having a certain amount of embryonic mortality.

Embryonic mortality often makes repeated breeding of cows necessary. Because they produce only one offspring at a time, embryonic mortality is serious in cows.

Animals that usually produce only one offspring at a birth sometimes produce twins. Dairy cattle twins are born approximately once in 50 births. Triplets are much more rare, and quadruplets even more infrequent.

Twins are produced in a variety of ways. Two eggs, each in a separate follicle, may be discharged and fertilized at the same time, or an exceptional follicle may contain two eggs that are discharged when the follicle

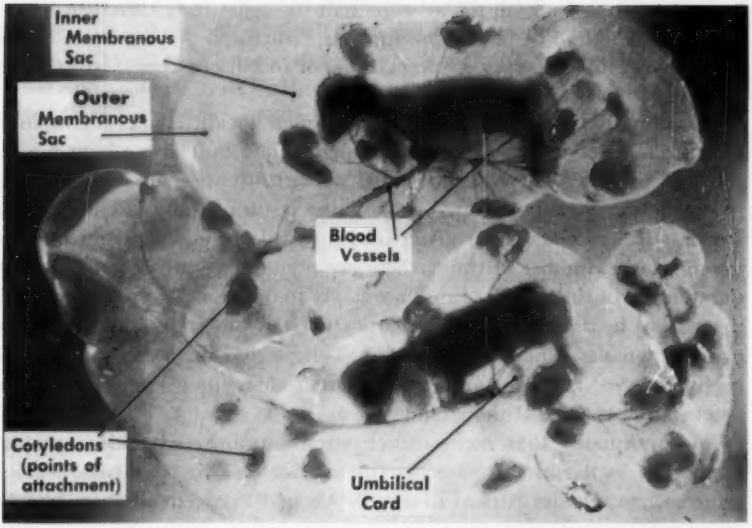

Figure 8. Twin fetuses taken from a cow at about four and one-half months of gestation. These twins are in the same set of membranes and are probably identical.

ruptures. In either of these cases, the twins are not identical; they may be of the same sex or of different sexes.

Following fertilization, a single egg occasionally divides into two parts. The two half eggs separate and each produces a complete, new animal. Two animals produced from the same egg and spermatozoon are identical in nearly all respects (see figure 8). They are of the same sex, and their markings and other external features are remarkably alike. Twins produced in this way are called identical twins.

Sex Determination

No other aspect of reproduction has excited more speculation or produced more theories than the question of how the male and the female are produced. The sexes apparently are determined by chance and much economic advantage would accrue if one were able to predetermine sex at will.

Research has shown that sex in farm animals, except birds, is determined by the spermatozoon that fertilizes the egg. Male-producing and female-producing spermatozoa are made in equal numbers by each testis and are intimately mixed in the semen. It is a matter of chance which type

fertilizes the egg, and, on the average, half the eggs are fertilized by male-producing and half by female-producing spermatozoa. Attempts are being made to sort the two types of spermatozoa or to kill one type, and to leave the other intact.

Occasionally litters of pigs are born all male or all female; a cow in a long series of calvings produces all of one sex, or a bull sires a long run of calves of one sex. These results, which attract attention because of their strangeness or their rarity, are probably the result of chance. The chances are practically even that a given offspring will be male. If a penny is tossed a large number of times, there are occasional "runs" of heads and the number of times such "runs" are likely to occur in a given number of throws can be determined mathematically. It is the same with "runs" of males or females. There is no reason to believe that the law of chance has been disobeyed and that an influence other than those known has been determining the sex of the young.

An abnormality that excites much attention, although it is comparatively rare, is the birth of freemartins in cattle. This condition usually results when a heifer is twin to a bull. About 94 percent of these female twins are freemartins, sterile and unfit for breeding. Dissection shows that the internal organs are a mixture of male and female (see figure 9). In

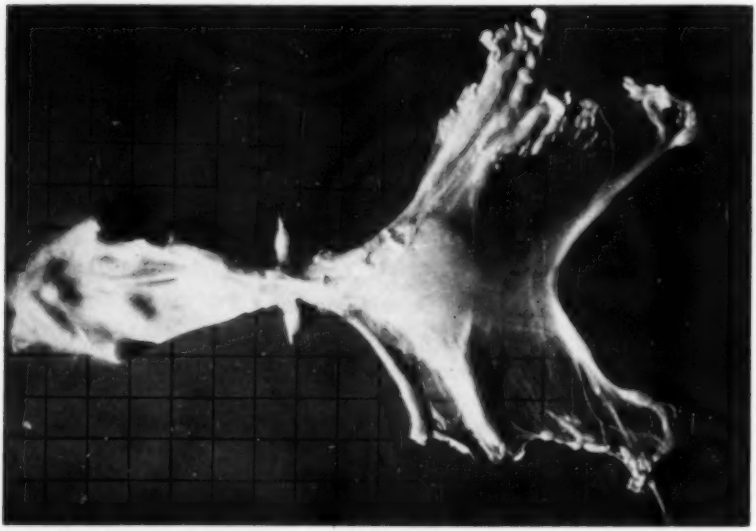

Figure 9. Reproductive organs from a freemartin heifer. These may be contrasted with normal organs shown in figure 14.

these twins the placentae, or attachments to the uterus, have been so close together that their blood vessels have joined, and blood from one twin passes to the other. The secretions from the male twin alter the formation of the reproductive tract of the female, but the female secretions have no effect on the sex organs of the male.

Nutrition and Fertility

Although the mechanisms through which dietary energy exerts its influence on reproduction are not known, the plane of nutrition imposed at various stages of the reproductive cycle and at various stages of life influences reproductive performance. A low nutrition level during early life greatly retards the onset of puberty in cattle, but has very little effect on swine. At the time of puberty, cattle, whether bulls or heifers, are of about the same size regardless of the plane of nutrition, but the boar and gilt reared on high levels of energy are much larger at the time of puberty than are their mates fed a low-energy ration.

The effects of feeding level upon the number of services required for conception in cattle have varied from trial to trial. In the Cornell experiments, heifers reared on low planes of nutrition have had smaller calves than their mates grown on a high level of feeding but, in proportion to the dam's weight, the calves dropped by low-level heifers are larger than those born to high-level heifers. Although low-level heifers suffer more calving difficulty they conceive for subsequent pregnancies equally as well as heifers that had been fed larger amounts of energy during early life. There is a definite tendency for cows that were reared on a high plane of nutrition to encounter breeding difficulties later in life and, thereby, to have a shorter productive life than do cows reared on a low energy intake. These facts refer to the subsequent effects of early nutritive levels. All the cows were fed alike after the first calf had been born.

Feeding level does not affect the fertilization rate in sheep or swine. In both the pig and sheep, a high plane of nutrition for three or more weeks prior to mating favors a high rate of ovulation, and a low plane of nutrition imposed after mating is conducive to a high rate of embryonic survival. Whether or not survival of the newborn would be improved by a high plane of nutrition needs further study.

Management Practices and Fertility

Exercise promotes good health and may have some beneficial effect on reproductive efficiency. The male is likely to have too little exercise, particularly during the winter. A male properly exercised is not only able to perform his duties better but he is often more manageable through fre-

quent handling and familiarity with his attendants and surroundings. Exercise cannot be too strongly stressed as a factor in the management of breeding stock.

Anything that lessens the vigor of an animal tends to reduce his breeding capabilities. Such things as damp, cold surroundings, a generalized disease, or any debilitating condition will have a bad effect. Extra feed of a suitable kind, or delay of mating for a short time, may improve the condition of these animals so that they may be bred. A little extra thought for the comfort of animals, particularly for those on whom great demands are being made in service or milk yield, will be amply repaid.

Drugs should not be used to stimulate weakened reproductive powers. Substances such as yohimbine, cantharides, or any of the sexual stimulants that are on the market, act by increasing the blood flow to the reproductive tract and temporarily increasing sexual desire. They increase exhaustion at a time when rest and change of management are needed. Attention should be paid to the health and general condition of animals. Unless there is a specific disease to be combated, drugs are harmful. If exercise and judicious management do not correct the trouble, drugs are not likely to be beneficial. They should be given only on a veterinarian's advice.

Artificial Insemination

Artificial insemination is now a recognized part of animal husbandry routine. Many cooperative artificial breeding circuits have been set up in New York State, and semen is distributed to these from a central bull establishment in Ithaca. Information on these developments may be obtained from the Department of Animal Husbandry at Cornell University. Each year the number of cows bred per bull is being increased. By the use of new methods, one bull may be used to inseminate thirty thousand cows in a year.

Artificial insemination has also been used for sheep with varying degrees of success. Some Russian workers have reported results of artificial insemination that were superior to those obtained by natural breeding. English and New Zealand workers, however, have had much poorer results. Recent research has shown that artificial insemination is practical in swine.

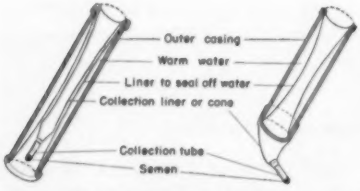

Figure 10. Diagrams of two types of artificial vaginas for collecting semen from bulls.

Semen is collected from the male with an artificial vagina (see figure 10). It is then mixed with a suitable diluting medium containing egg

yolk or heated milk and antibiotics and cooled slowly to 40° F. for storage and shipping. If the temperature is lowered too rapidly the spermatozoa are damaged and frequently killed. If they are kept at body temperature they lose their vitality within a few hours. The lower temperature reduces sperm activity and increases their life span. When they are placed in the female tract, activity returns. Penicillin and streptomycin control bacteria and prevent their by-products from harming the sperm.

For best results, artificial insemination must be properly timed in relation to the release of the egg from the ovary. This release time varies from the middle of the heat period in some species to 12 hours after the end of the heat period in others. This factor will be discussed for each species later in the bulletin.

By using a special method, which includes the addition of glycerol to the diluting medium, bull semen has been frozen and held at very low temperature (—110° F.) for as many as four years without complete loss of fertility. Its use after shorter periods is now common practice. Experiments are now in progress that, if successful, will enable semen to be held for a reasonable time without cooling. This should make artificial insemination much easier to carry out.

The stallion produces several ounces of semen at a service, the bull about 1/4 of an ounce, the ram about 1/20 of an ounce, while the boar yields 10 to 15 ounces. The extremely small size of the spermatozoa may be gathered from the fact that in these quantities that there are from 2,000,000,000 to 14,000,000,000 or more spermatozoa. Theoretically, only a single spermatozoon is necessary to fertilize an egg, but in practice countless numbers perish in their passage up the female tract. Nature provides for this wastage by the ejaculation of an enormous number of spermatozoa at each service. This large excess of spermatozoa makes artificial breeding practical. Research has shown that as few as 10,000,000 live sperm per insemination will yield the maximum conception rate in dairy cattle. This means that one ejaculation may be used to breed from 500 to 1000 cows if it is properly handled and diluted. Figure 11 illustrates the insemination of a cow.

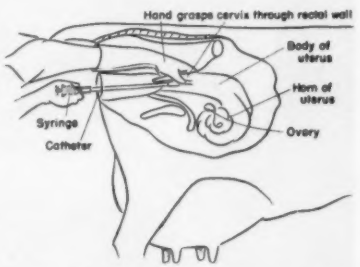

Figure 11. Diagram of most widely used method for artifiicially inseminating dairy cattle—rectal fixation of cervix.

THE FARM ANIMALS

Cattle

Cows differ from most other animals whose reproductive behavior is known in that they come in heat at regular intervals all the year round.

The interval between heat periods is usually stated as three weeks, but individual cows vary so that the interval may be as short as 17 days or as long as 24 days. Shorter and longer periods occur but these are considered abnormal. The duration of heat is variable, and is, on the average, about eighteen hours; it tends to be shorter in winter and more difficult to detect. The egg is usually shed from the ovary about 12 hours after heat has ceased, but there is considerable variation in this time. The cow has a low level of activity in regard to the chemical substances, or hormones, that regulate the reproductive processes. This may be a factor in causing the duration of heat to be short compared with that of the pig or of the ewe. Also, the ovary produces a low level of estrogens and the requirement is low. After this hormone has been operating for a few hours it ceases to have an effect. This point is reached early in the development of the follicle so that the cow goes out of heat before the egg is shed, a condition unknown in any other species except in certain bats.

Some changes which take place in the cow's reproductive tract, especially the ovary, during the estrous cycle are shown in figures 12 through 16. In figure 12 the reproductive tract is that of a Holstein heifer slaughtered four days after heat. A new yellow body may be seen on the ovary but it appears larger than normal because it contains an unusually large amount of blood left from the rupturing of the follicle.

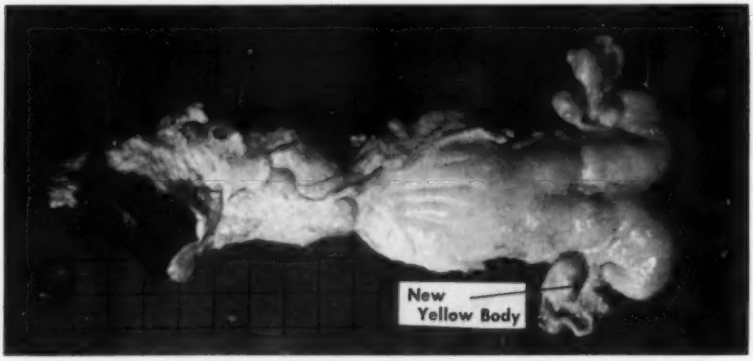

Figure 12. Reproductive organs from a heifer slaughtered four days following heat.

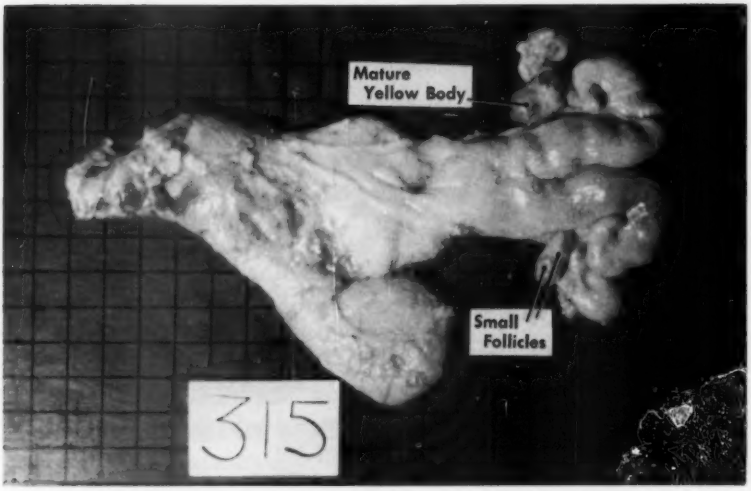

Figure 13. Reproductive organs from a heifer slaughtered ten days following heat.

The reproductive tract in figure 13 was taken ten days after heat. Note the mature yellow body on the left ovary. The right ovary has three small follicles. These follicles will probably degenerate, although one may continue to grow and liberate an egg at the next heat period.

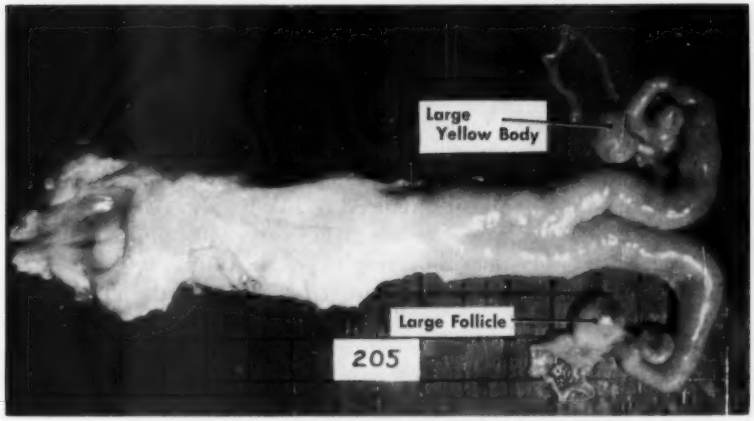

Figure 14. Reproductive organs from a heifer slaughtered 16 days following heat.

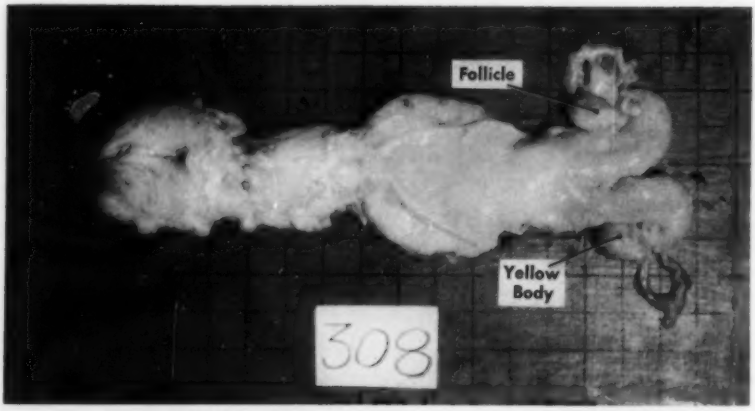

Figure 15. Reproductive organs from a heifer slaughtered 19 days following heat.

By the 16th day following heat, a picture similar to that shown in figure 14 may be seen. A large yellow body is present in the left ovary and a medium size follicle in the right one. At this time the yellow body is decreasing its output of progesterone while the follicle is beginning to produce estrogen that eventually will bring the cow into heat.

Nineteen days after the previous heat period, the organs are preparing for the next one which is only two days away. Figure 15 shows that the yellow body has decreased in size and the follicle is somewhat larger. The estrogen produced by the follicle is increasing the blood supply to the uterus. The muscle layers of the uterus are becoming firmer as they contract.

On the day of heat, the follicle has reached its peak in size and function. Figure 16 shows a large follicle protruding from the surface of the left ovary. This ovary still contains a yellow body but it probably is not producing a significant amount of progesterone at this time. The large follicle will break about 12 hours after the end of standing heat and release the egg. A small follicle is present on the right ovary. This follicle will probably degenerate rather than rupturing to release an egg.

The symptoms of the onset of heat are not marked, but the most reliable indications are restlessness, a tendency to bellow and to mount and be mounted by other cows. A slight swelling of the vulva and a flow of mucus are also signs. The condition of full heat or "standing heat" is not reached until the cow allows herself to be mounted by others. When she is in the barn tied in her stall, heat is more difficult to detect than it is when she is running with others in the field. A recommended procedure for catch-

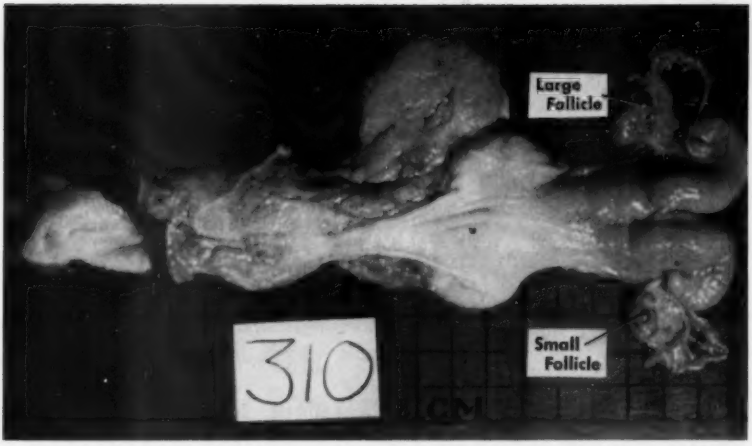

Figure 16. Reproductive organs from a heifer slaughtered while in heat.

ing cows in heat is to turn all cows out in the morning so they can exhibit the symptoms of heat and get some exercise. Cows that are expected in heat should be turned out and watched again in the afternoon. They should be observed for about a half-hour each time.

Some techniques have been worked out by which the heat cycles of cows can be altered. This may have practical application in breeding beef cattle artificially if a number of cows can be brought in heat at the same time. However, additional research is needed before the techniques can be recommended for general use.

Some cows (45 percent) and more frequently, heifers (90 percent) bleed from the vulva about two days after the beginning of heat. It is believed by many that absence of this bloody discharge indicates that service has been successful, but this is not so. It is only an indication that the cow has been in heat.

The best results are obtained when the cow is bred during the second half of the standing heat period. They should not be bred earlier than six hours after the beginning of standing heat nor later than six hours after its end. However, a small percentage of cows do conceive when they are bred outside of this range. Because cows cannot be watched continuously for signs of heat, the general recommendations are as follows: cows first noticed in standing heat in the morning should be bred during the afternoon of the same day; cows first observed in heat in the afternoon should be bred before noon the next day.

The duration of pregnancy is about nine months in the cow but it varies slightly for different breeds. The average gestation periods for the five major dairy breeds are shown in table 1.

Table 1

Average Gestation Periods for Cows by Breeds

Breed	*Number of Days*
Brown Swiss	288.4
Guernsey	282.7
Ayrshire	278.2
Holstein	278.6
Jersey	277.9

The male is usually carried about a day longer than the female. Live calves born after seven months are frequently viable, but they require special attention and are more difficult to rear.

The age at which heifers come in heat for the first time depends greatly on how well they have been grown. An experiment was conducted at Cornell in which three groups of Holstein heifers were grown at different rates. The nutrient levels were designed to furnish 60 percent, 100 percent and 140 percent of the total digestable nutrients recommended by Morrison for growing dairy heifers. The average age at the time of the first heat period was 9, 11½ and 18 months for the high, medium and low levels respectively. The average weight at first heat for these heifers was 596, 597 and 532 pounds respectively for the high, medium and low levels. The occurrence of first estrus was more closely related to size than it was to age. (Cornell University Experiment Station Bulletin 936 contains additional information on the influence of underfeeding and overfeeding on growth and development of Holstein heifers.) Jersey and Guernsey heifers grown similarly would come in heat a little earlier. Since size does influence the age at which puberty occurs, it seems natural to consider size in relation to time of breeding. The usual recommendation is to breed Holstein heifers at weights between 700 and 850 pounds. Even heifers raised on the medium level of nutrition reached this weight by 15 months of age and had they been bred they would have calved at 24 months of age. This is an important consideration in herds practicing seasonal calving. Heifers that have been poorly grown should not be bred until they have attained the desirable size. If they are bred before this, special care should be given them.

Cows should be checked for pregnancy about 60 days after breeding. Although the absence of heat following breeding is a strong indication of pregnancy, it is not proof. Several conditions can cause the absence of heat even though the animal is not pregnant (see Cornell Extension Bulletin 737). A pregnancy check can be made by feeling the reproductive

Figure 17. Cows in barnyard for heat checking. Cow standing to be mounted is in heat.

organs through the rectum. This should be done by an experienced person, preferably a veterinarian. Some chemical and biological tests for pregnancy have been proposed, but none has proven practical to date. The old method of pregnancy diagnosis known as "bumping" is still used by some dairymen. However, this can not be used until about seven and one-half months of pregnancy and is too late to be of much value. Even though veterinarians do charge for pregnancy checks, the time and money saved more than pay the cost involved. In herds visited by the Cornell mobile laboratory team, cows thought to be six months pregnant were found to be open and in need of treatment. If these cows had been checked for pregnancy at 60 days as much as four months might have been saved in getting them settled. This delay could amount to a $200 loss in milk production for a good cow.

Signs of approaching freshening are a swelling of the udder, particularly marked in first-calf heifers. This becomes very noticeable about a week before calving. The vulva swells and the ligaments around the tail head sink. Birth takes about one to two hours; the afterbirth is expelled, on the average, about five hours after the birth of the calf. The calf always should be given the colostrum, or first milk of the dam. This fluid acts as a purge and also contains the antibodies, or disease-resisting substances, that have been built up in the blood of the mother. They help the calf to resist the

diseases to which it is most likely to be exposed. Digestive troubles also frequently follow in calves that are not allowed colostrum; these may be avoided to some extent by feeding antibiotics with normal milk.

If abortion takes place in a cow before the fifth month of pregnancy, no extra milk is produced after the abortion. The milk-secreting portion of the udder begins to develop after the fifth month; the later the abortion occurs after this time, the more udder development has been made and the more milk is given by the dam, provided no complications have occurred. In addition to udder development, hormones probably play an even greater role in increased milk production following late abortions. The hormones dealing with lactation are produced in larger amounts following calving and abortions.

Cows should not be bred earlier than 60 days after calving and then only if they had no complications following their calving. This amount of time is required by the uterus if it is to return to normal after calving. A wait of 60 days allows time for two services, if necessary, within a calving interval of approximately 12 months. The conception rate increases as the interval between calving and breeding lengthens up to about 90 days. Table 2 gives the results of an experiment in which cows were bred at different intervals after calving.

Table 2

Fertile Cows Bred at Varying Intervals of Time Following Calving

Days After Calving	*Number of Cows*	*Percent Settled First Service*	*Services Required Per Conception*
50 or less	26	31	2.5
51 to 60	24	67	1.7
*61 to 90	50	70	1.6
90 or more	50	76	1.5

*Recommended time to breed.

Bulls raised on three levels of nutrition similar to those used in the experiment described for heifers produced viable semen at 37, 43 and 51 weeks of age respectively for the high, medium and low levels. For additional information on "The Effect of Underfeeding and Overfeeding on the Development of Holstein Bulls," consult Cornell Experiment Station Bulletin 940. These results clearly indicate that the age at which bulls can be put in service varies markedly with different feeding practices. It has often been stated that a yearling bull should only be allowed to breed 10 to 15 cows during the year, and these breedings should be well spaced. Experience in artificial breeding indicates that young bulls may be used much more frequently. It is common practice to start bulls in service at 12 months of age. They are used on a weekly schedule for periods ranging

from nine months to two years, and in some cases longer, without apparent harm. Mature bulls have been collected regularly twice a week for extended periods of time with no decrease in activity or production of sperm. A group of mature bulls were collected daily for eight months in an experiment at Cornell. These bulls were compared with a similar group of bulls that were collected once each week. The bulls collected once per day produced an average of 23.6 billion motile sperm per week while those collected once per week produced only 11.1 billion. The fertility level was not different for the two groups of bulls during the experimental period. This demonstrates that yearling bulls can be used on the average once each week or possibly more often. An average of one service per day may be obtained from mature bulls without affecting their fertility level. It must be admitted, however, that there may be individual differences between bulls and that some may not be able to stand the vigorous service described above.

It is usually recommended that the young bull may be run with a herd of 10 to 15 beef cows, while the mature bull may be entrusted with a herd of 30 to 35 cows.

Horses

The breeding season of the mare, although long, is restricted to a certain period of the year, usually from April to August, but the individual animal and breed variability is great. Some mares continue in heat at intervals until fall. Most studies have shown, however, that conception is very low for mares bred outside the usual breeding season. The length of the heat periods is also variable, with 74 percent ranging between two and eight days with an average of five days. The interval between heats varies from 14 to 28 days, with an average of three weeks. The mare comes in heat again after foaling from the seventh to the eleventh day, or, on the average, about the ninth day. It has been said that at this time she may be served with a greater chance of success than at other times, but recent work has not substantiated this statement. Conception rates of only 43 percent have been reported for mares bred during the foal heat and abortion rates have been as high as 15 percent to 25 percent. This heat period lasts for a much shorter time than the usual period. Suckling tends to delay the onset of heats after the short or foal heat.

The signs of estrus in the mare are general irritability, frequent urinations, and movements of the clitoris.

Service early in the heat period is not so likely to result in pregnancy as it is at a later stage of heat, because the egg is shed late in the period. Spermatozoa have a limited life in the female tract, and if they are deposited there early they do not survive until the time when the egg is shed.

Consequently, if the mare is served early in the period, she should be served three days later to increase the chances of survival of spermatozoa. A further service may be necessary if the mare has a very long heat period. It is useless, too, to force the mare to take the stallion; if she is not well in heat it is not likely that ripe eggs are present in the ovaries.

Mares should be bred regularly. There is a tendency to breed them at more irregular intervals than any other class of livestock. The frequent bursting of follicles tends to cover the ovaries with scar tissue making it more and more difficult for eggs to be shed. Cysts form and the mares become irregular or continually in heat. If the condition is neglected, it usually becomes worse. Such mares are restless and unmanageable. Removal of the ovaries effects a cure for the restlessness but leaves the mare sterile.

The indications of pregnancy in mares are an absence of heat periods followed by an increase in the size of the abdomen and a disinclination to take violent exercise. These are indications and are not to be relied on absolutely. Occasionally a mare will take the stallion during pregnancy, and a bulky abdomen may be the result of heavy roughage feeding. Movements of the fetus may be felt at about the beginning of the second half of pregnancy. Recently biological methods have been worked out by which pregnancy may be diagnosed accurately after sixty days. Some veterinarians diagnose pregnancy in mares by feeling the reproductive organs through the rectal wall. At the ninth month the udder grows noticeably and the skin over it becomes soft. The points of the teats may become coated with a wax-like substance a few days before the mare foals.

The duration of pregnancy is variable: the average is 48 weeks. Thoroughbreds usually have a longer pregnancy than do the draft breeds. A mare carrying a mule foal has a longer pregnancy than if she is in foal by a horse. Moderate exercise and a light laxative diet should be given to mares just before they foal. The duration of birth is normally short. If a delay occurs, the foal is in danger of suffocation because the afterbirth separates from the wall of the uterus early. The mare should be assisted in such cases. The afterbirth usually comes away about half an hour after foaling. If it is retained for more than six hours, veterinary advice should be obtained.

The filly comes in heat at about one year of age, but she should not be bred until she is three years old. She should be bred regularly at first, but as she grows older it is advisable to allow her occasional rests. A continuous series of pregnancies is a great drain on a mare, twelve in succession usually leave her useless for any purpose. Occasionally a filly may be sufficiently well developed to be bred at two years of age. If this is done, she should be watched closely and given every possible attention; she

should not be bred again at three years of age, but should have a rest and rebred at four years of age.

The stallion may be used for breeding at two years of age. The frequency with which he should be used at this age is not known; however, according to the best available information, 10 to 15 mares could be served. At three years of age he may serve up to 25 mares, but he should not be allowed more than one service a day. He may gradually work up to 80 or 90 mares with two services daily during the height of the breeding season.

Sheep

The ewe has a somewhat more restricted breeding season than do other classes of livestock. Ewes usually come in heat in the fall, about September to November and, if not bred, will continue to come in heat until January or February. The average duration of heat is 27 hours, although there is some variation. The egg is shed from the ovary about the time the ewe is going out of heat. The average interval between heats is 16½ days. From the end of pregnancy, or from the end of the breeding season, the reproductive tract is inactive until the following fall.

In some breeds such as the Dorset Horn and the Merino, heat periods continue over a much longer period of the year. Animals of these breeds may be mated at any season, and can be used for the production of hothouse lambs. Selection of ewes with longer breeding seasons might produce strains with similar potentialities.

Much research has been done in an attempt to extend the breeding season of sheep. It has been found that progesterone injections given daily or every other day for six to twelve days, followed by a single injection of gonadotrophic hormone, will bring ewes in heat and cause ovulation. This may be done at any time of the year, but the fertility level is highest when the treatment is started about six weeks ahead of the regular breeding season. The development of slowly, uniformly absorbing preparations, coupled perhaps with the replacement of pregnant mares serum by a cheaper gonadotropin, would make the control of heat and ovulation in this manner a practical measure.

Small doses of gonadotrophic hormone have made it possible to increase the number of lambs born per ewe. When this material is injected on the 11th to 13th day of the cycle, the number of eggs shed at the subsequent heat period is increased. Such treatment has been reported to raise lambing percentages by about 30 percent.

Ewe lambs come in heat during their first fall, but they should not be mated at this time because they are not sufficiently well grown. Some authorities advise breeding lambs providing the offspring are not kept

in the breeding stock. Too little systematic experimental work has been done to recommend the practice.

The signs of heat are not very apparent in the ewe, but this is unimportant if the ram is with the flock at breeding time. Usually a loss of appetite and restlessness are evident at this time. Where hand coupling is resorted to, it is advisable to run a teaser ram with the flock with an apron hung in front of the penis to prevent service. Better still is the use of a ram with the canals leading from the testes to the penis cut, so that the ram mounts the female and serves but does not impregnate her. The teaser ram should be marked on the chest with heavy lubricating oil or grease mixed with lamp black, yellow ochre, ventian red or blue. This enables the ewes that have been mounted to be sorted at a glance.

Signs of pregnancy are the absence of heat periods and gradual enlargement of the belly of the ewe. At a late stage of pregnancy the rebound of the fetus may be felt by pressing sharply on the abdominal walls in front of the udder. The signs of approaching lambing are an increase in the size of the udder, especially marked a day or two before lambing, and a swelling of the vulva. A ewe about to lamb often goes away from the rest of the flock. The act of birth lasts about an hour. Twins or triplets usually are born about one-half to one hour apart. The membranes are generally expelled two hours later. The newborn lamb usually is covered with mucus that should be removed from the mouth and nostrils at once to prevent the lamb from suffocating. The duration of pregnancy is from 142 to 154 days, but it is rather longer for the late-maturing breeds such as the Merino.

A ram lamb may be used for service very sparingly if he is well grown, but he should not have more than 12 to 15 ewes to serve. It is better that hand coupling be used for these young rams. An 18-months old ram can serve a flock of 35 to 40 ewes; a vigorous mature ram may be entrusted with 50 ewes. If hand coupling is used exclusively, a young ram can serve from 50 to 60 ewes, and an old one 75. It is better to divide a large flock into smaller ones, each with one ram than to run two or more rams together. They tend to interfere with one another, and the stronger ram serves the greater number of sheep. There is also doubt about which lambs are the offspring of any one ram, and the breeding capabilities of each ram are unknown. Rams should always be marked with colored grease in order that the service date of the ewes may be recorded and preparations made for watching them at lambing time if necessary.

Ewes served early in the season tend to produce more twins and more vigorous lambs than those served later. This is because the more vigorous ewes tend to breed earlier than the others.

In selecting lambs for future breeding stock, one should remember that

singles get more milk than twins, grow faster, and are often larger at the time of selection. Twins, although a little smaller because of the nutritive conditions, carry the same genetic growth factors with additional ones for greater fertility. To increase the lambing percentage, well-grown twins should be given preference over singles, although the singles may be slightly larger in size. The best time for the selection of breeding lambs is when the lambs are to be marketed. The most accurate selection can be made at this time because the lambs have marketable characteristics best developed.

Swine

The sow has a long breeding season, probably extending over the whole year except when she is pregnant or suckling. The duration of heat is variable. The large black breeds have an average heat period of 62 hours; the large white breeds stay in heat, on the average, only 48 hours. The interval between heats varies from 18 to 24 days, and averages about 21 days.

Mature sows shed 12 to 20 eggs from the ovaries at each heat period, but several of the eggs are lost and some young embryos perish, reducing the number of young animals that develop to birth. The fertility of strains within the different breeds varies greatly. The average litter size probably could be improved by selection. Larger litters, within reason, are not detrimental to the offspring because high fertility and high milk yield usually are associated.

A gilt usually reaches sexual maturity at three to five months of age, but she should not be bred until she is six to nine months of age; weight is the more reliable indication of the time to breed. Gilts should be bred at a weight of about 180 pounds or more in order that they farrow at about 12 months of age. Sows come in heat about three to five days after farrowing, but they should not be bred at this time because a heavy milking sow cannot develop young in the uterus while she is feeding a litter. Another heat usually occurs three to five days after weaning, and the sow should be bred at this period. Two litters a year should be the aim of the breeder. The sow will produce young until she is from five to seven years of age.

The heat period is preceded by a swelling of the vulva and a slight discharge. In addition to the swelling, which continues during heat, the sow shows general excitement and often follows other sows, sniffing at their genital organs and often jumping them, while grunting in a peculiar fashion. If the sow stands to be mounted by others or if she stands when a hand is placed firmly on her back, she probably is in heat. Eggs are shed about 35 hours after the beginning of heat. The vitality of the eggs is not retained for more than a few hours after they have been shed; therefore,

the second day of the heat period is the most favorable for service. In gilts the eggs are shed earlier than they are in sows.

The duration of pregnancy is about 16 weeks, but it varies from 109 to 125 days. In addition to the usual signs of approaching birth such as swelling of the vulva and development of the udder, the sow collects straw and other materials for a nest. Usually the whole litter is born within an hour, but occasionally the process is prolonged. The interval between the births of individual animals may vary from a few minutes to an hour, often with a longer interval before the birth of the last member of the litter. Sows, if left to themselves, may eat the piglings as well as the afterbirth. This may be prevented to a large extent by feeding them a diet containing suitable kinds and amounts of protein and minerals before farrowing. The use of a special farrowing crate is also an advantage.

The boar may be used sparingly at eight or nine months of age if he is well grown. He should not be allowed to serve more than once a day, with 12 to 15 services during the season. When a year old, he may be used 25 to 30 times during the season, gradually increasing this number to 50 or 60 for a two or three-year old boar. Young boars should not be run with a group of older sows. An older sow in heat may injure the boar and leave him incapable of regular service.

Pigs seem to be particularly susceptible to the ill effects of inbreeding. Fertility tends to be reduced, and the quality of the offspring tends to be poor. A strong tendency to hermaphoditism, or a mingling of the two sexes in one animal, which the pig shares with the goat, also is intensified by close inbreeding.

Further Reading

The following references are recommended as a guide for those who wish to read further in the subject of animal reproduction.

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